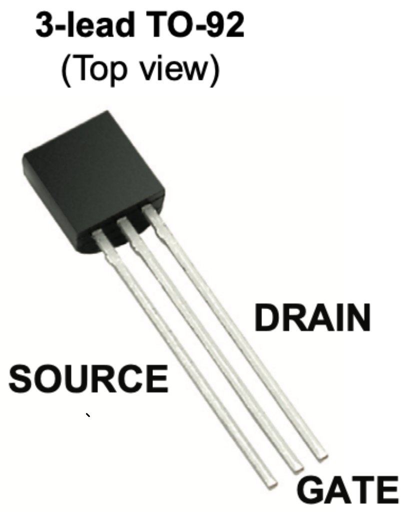
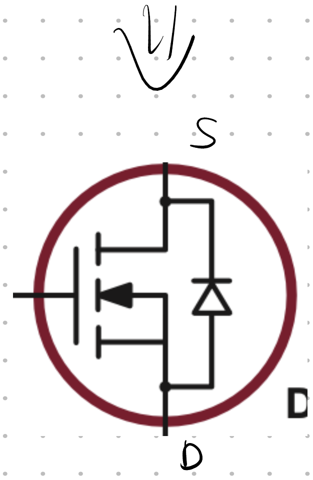
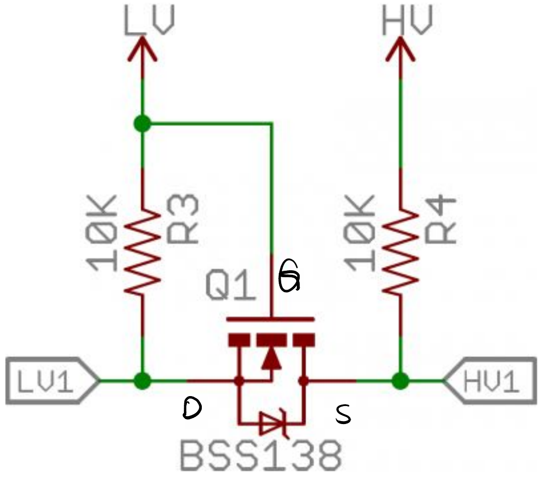
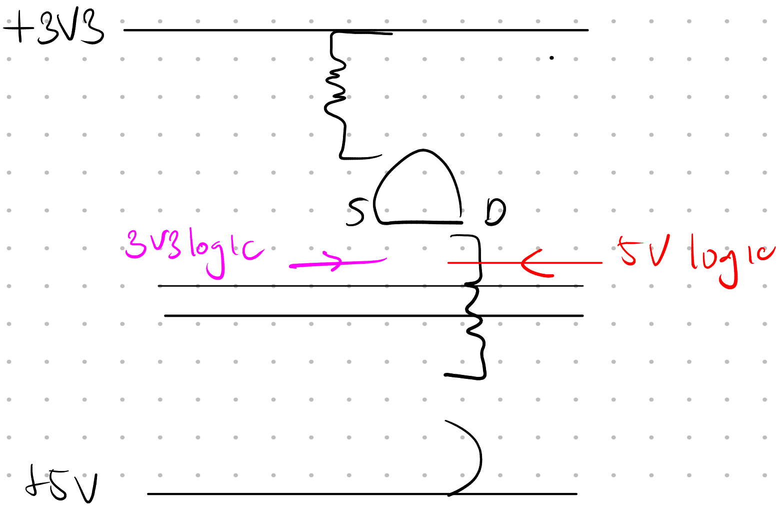



from stack exchange:
https://electronics.stackexchange.com/questions/555631/understanding-how-this



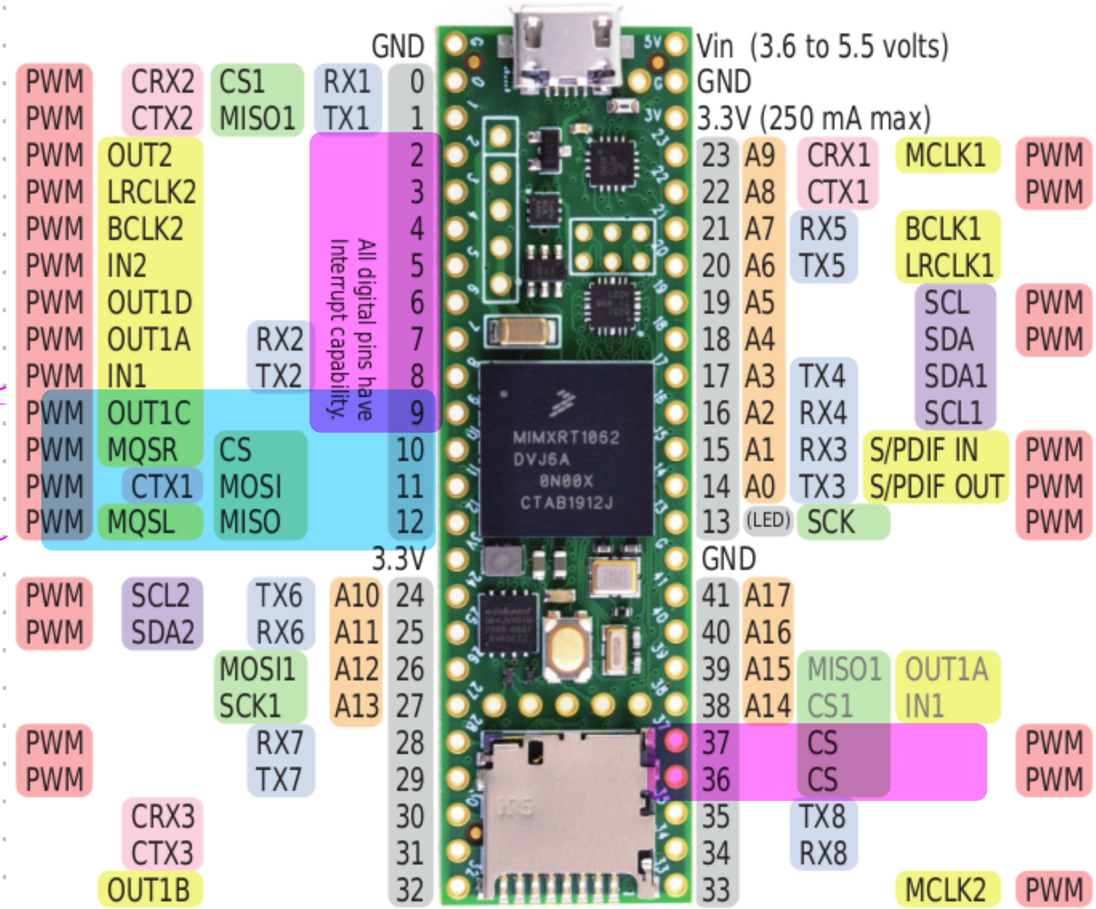

5v 3v3

| test | | output | |
|---|---|---|---|
| '0' | '1' | '0' | '1' |
| 0v | 5v | 0v5081 | 3v339 |
| 0v | 3v3 | 0v5081 | 3v339 |

in conclusion: using the 2n7000 isn't going to work bc it doesn't pull the ckt high enough on the 5v output

WRONG CONCLUSION

flip the source and drain --> the LV and HV sides and it works just fine!
the problem from before was that the gate was NOT pulled high enough (translation: I didn't connect the gate correctly the first time)


GND
0 1 2 3 4 5 6 7 8 9 10 11 12
3.3V
24 25 26 27 28 29 30 31 32
RX1 TX1
CS1 MISO1
CRX2 CTX2
OUT2 LRCLK2 BCLK2 IN2 OUT1D OUT1A IN1 OUT1C MQSR MQSL
RX2 TX2
CS MOSI MISO
CTX1
All digital pins have Interrupt capability.
PWM
A10 A11 A12 A13
TX6 RX6
MOSI1 SCK1
RX7 TX7
SCL2 SDA2
CRX3 CTX3
OUT1B
Vin (3.6 to 5.5 volts)
GND
3.3V (250 mA max)
23 22 21 20 19 18 17 16 15 14 13
A9 A8 A7 A6 A5 A4 A3 A2 A1 A0
(LED)
CRX1 CTX1
RX5 TX5
TX4 RX4 RX3 TX3
SCK
MCLK1
BCLK1 LRCLK1
SCL SDA SDA1 SCL1
S/PDIF IN S/PDIF OUT
GND
41 40 39 38 37 36 35 34 33
A17 A16 A15 A14
MISO1 CS1
OUT1A IN1
CS CS
TX8 RX8
MCLK2
MIMXRT1062 DVJ6A 0N00X CTAB1912J

Gps

IMU1

INT

Extended Complementary Filter (with notes)

$${}^{I}_{G}q = \sum \dot{q} \cdot \Delta t \quad (1)$$

rate of change of q can be approximated using

$${}^{I}_{G}\dot{q} = \frac{1}{2}\,{}^{I}_{G}\hat{q} \cdot \begin{pmatrix} 0 & (\omega - ke) \end{pmatrix}^{T} \quad (2)$$

gyroscopic error 'e'

* if k is small, ω is considered more

error calcs: → 3-24

reference for gravity:

$$\vec{v}_{r(a)} = \begin{pmatrix} 0 & 0 & -1 \end{pmatrix} \quad (3)$$

using estimates $q = (q_w \; q_x \; q_y \; q_z)$:

$${}^{L}\vec{v}_{r(a)} = q\,\vec{v}_{r(\vec{a})}\,q^{-1} = R_q \vec{v}_{r(\vec{a})}$$

(5) (6)

$$R_q(\vec{q}) = \begin{pmatrix} q_w^2 + q_x^2 - q_y^2 - q_z^2 & \cdots & 2q_xq_z - 2q_wq_y \\ \vdots & \ddots & 2q_yq_z + 2q_wq_x \\ \vdots & & q_w^2 - q_x^2 - q_y^2 + q_z^2 \end{pmatrix} \quad (7)$$

$$\vdots$$

$${}^{L}v_{r(\vec{a})} = \begin{pmatrix} 2(q_xq_z - q_wq_y) \\ 2(q_wq_x + q_yq_z) \\ 2(q_w^2 + q_z^2) - 1 \end{pmatrix}^{T} \quad (8)$$

from normalized $\vec{q}$ equation

error $e$ is calculated from two error terms. all vectors are normalized before calculations:


$$\hat{v} = \frac{\vec{v}}{|\vec{v}|} \quad (11)$$

$$e_a = \begin{pmatrix} x_\theta \\ y_\theta \\ z_\theta \end{pmatrix} = \hat{v}_{m(a)} \times {}^{L}\vec{v}_{r(a)} \quad (12)$$

to remove for magnetic incliination:

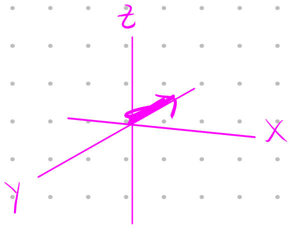
consider only x & z!

$$\vec{v}_{r(m)} = (v_{rx} \quad 0 \quad v_{rz}) \quad (13)$$

$$\vec{v}_{r(e)} = (0 \quad 0 \quad -1) \times (v_{rx} \quad 0 \quad v_{rz}) \quad (14)$$

$$= (0 \quad -1 \quad 0) \quad (15)$$

$${}^{L}\vec{v}_{r(m)} = q\,\vec{v}_{r(m)}\,q^{-1} \quad (16)$$




doing the same for magnetic inclination: (6), (7) --> (15), (16)

$${}^{L}\vec{v}_{r(m)} = \begin{pmatrix} 2(q_x q_y + q_w q_z) \\ 2(q_w^2 + q_y^2) - 1 \\ 2(q_y q_z - q_w q_x) \end{pmatrix} \quad (17)$$

$$\vec{e}_m = \begin{pmatrix} x_\theta \\ y_\theta \\ z_\theta \end{pmatrix} = \left| \hat{v}_{m(\vec{a})} \times \hat{v}_{m(\vec{m})} \right| \times {}^{L}\vec{v}_{r(\vec{m})} \quad (18)$$

these are here for some reason...

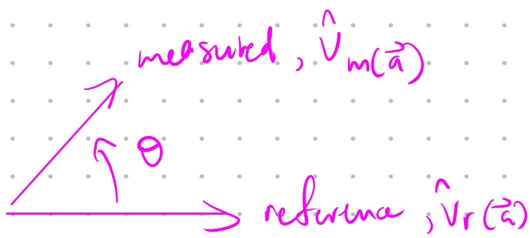
$$\vec{e} = e_a + e_m \quad (19)$$

but it needs to change based on the conditions

$$\vec{e} = \begin{cases} \vec{e}_a + \vec{e}_m & |\vec{v}_{m(\vec{a})}| > 0 \;\&\&\; |\vec{v}_{m(\vec{m})}| > 0 \\ \vec{e}_m & |\vec{v}_{m(\vec{m})}| > 0 \\ (0 \quad 0 \quad 0)^T & \end{cases} \quad (20)$$

apparently this can be conbined with the gyroscopic integration to provide with an accurate correction factor of gyroscopic drift.

B. Universal convergence:




this mathemtical relationship can be described using the scalar version of this formula where

$$0 < \theta < \pi \quad \text{(radians)}$$

so:

(estimate from the next timestep?)

$$|\vec{e}_a| = \underbrace{|\vec{v}_{m(a)}| \cdot |{}^{L}\vec{v}_{r(a)}|}_{1\text{, b/c they're normalized}} \sin\theta \quad (22)$$

$$\hookrightarrow |\vec{e}_a| = \sin\theta \quad (22a) \longrightarrow |\vec{e}_a| = \theta \text{ for small } \theta \quad (22b)$$

since the gravity error term is normalized, the formula simplifies to the above formulas

also, the proper gain K must be smaller than 1 to get a stable convergence!

C. Magnetic Disturbance rejection

magnetic sources, whether ferromagnetic or diamegnetic, are everywhere. it distorts the overall signal where it is around 0.2 to 0.65 Gauss when considering all possible locations (though it can be very consistent on a local scale!)

what Madgwick et al does is reject magnitudes above or below this range!

$$\vec{v}'_{m(m)} = \begin{cases} \vec{v}_{m(m)} & \text{for } m_{min} < |\vec{v}_{m(m)}| < m_{max} \\ (0\ 0\ 0)^T & \text{otherwise} \end{cases} \quad (23)$$

total error conditions, then, considering the above conditions:

$$\vec{e} = \begin{cases} \vec{e}_a + \vec{e}_m & |\vec{v}_{m(a)}| > 0 \ \&\& \ m_{min} < |\vec{v}_{m(m)}| < m_{max} \\ \vec{e}_a & m_{min} < |\vec{v}_{m(m)}| < m_{max} \\ (0\ 0\ 0)^T & \end{cases} \quad (24)$$

D. Magnetic Disturbance Compensation

there are a few reasons for why this is not an effective long-term solution. turning this off leaves the the IMU estimator susceptible to gyroscope drift. we have to add compensation. Keyframes are instances during a movement that define it and leaves interpolation to define the in-between frames.

Keyframes can be used to determine magnetic samples of minimal magnetic interference or gyroscopic drift.

this is achieved by calibrating hte gyroscopes and them performing the range of motions once.

quaternion q represents the movement due to accel and mag reference. so the accelerometer and magnetometer vectors that converge to q can be calculated by substituting 3 and 15 into 5 to produce the following values:

$\vec{v}_{sim(\vec{a})}$ & $\vec{v}_{SIM(\vec{m})}$

$$\text{ISBIO}: \vec{v}_{r(\vec{a})} = (0\ 0\ -1)^T \quad (3)$$

$$\vec{v}_{r(\vec{m})} = (0\ -1\ 0) \quad (15)$$

given

$$\vec{v}_{SIM(\vec{a})}(\vec{q}) = \vec{q}\, \vec{v}_{r(\vec{a})} \vec{q}^{-1} \ \& \quad (25)$$
$$\vec{v}_{SIM(\vec{m})}(\vec{q}) = \vec{q}\, \vec{v}_{r(\vec{m})} \vec{q}^{-1}$$

each keyframe therefore consists of these two 3D vectors.

whne magnetometer is unavailable, accelerometer is compared against V_sim(a). the keyframe with the smallest differences between the two frames is taken as the system estimation.

$$\vec{e}_{sim(m)} = \hat{v}_{m(\vec{a})} \times \hat{v}_{SIM(m)} \times {}^{L}\vec{v}_{r(\vec{m})} \quad (26)$$ rotated vector using prev q

$$\vec{e} = \begin{cases} \vec{e}_a + \vec{e}_m & |\vec{v}_{m(\vec{a})}| > 0 \ \&\& \ m_{min} < |\vec{v}_{m(m)}| < m_{max} \\ \vec{e}_a + \vec{e}_{sim(m)} & |\vec{v}_{m(\vec{a})}| > 0 \\ (0\ 0\ 0)^T & \end{cases}$$

---

Compare:

$$\vec{e}_m = \begin{pmatrix} x_\theta \\ y_\theta \\ z_\theta \end{pmatrix} = \hat{v}_{m(\vec{a})} \times \hat{v}_{m(\vec{m})} \times {}^{L}\vec{v}_{r(\vec{m})} \quad (18)$$

$$\vec{e}_{sim(m)} = \hat{v}_{m(\vec{a})} \times \hat{v}_{SIM(m)} \times {}^{L}\vec{v}_{r(\vec{m})} \quad (26)$$

E. Gain K

I guess K is able to change. in normal use, K will be low so the gyroscopic integration can be incorporated. See (2). it's defined as K_norm. that's the K that's used in normal conditions. for initial convergence, it should be K_init and should transition to K_norm. the following is (28).

$$K(t) = \begin{cases} K_{norm} + \dfrac{t_{init} - t}{t_{init}}\left(K_{init} - K_{norm}\right) \\ K_{norm} \end{cases} \qquad (28)$$

$$K(t) = \begin{cases} K_{norm} + \dfrac{t_{init} - t}{t_{init}}\left(K_{init} - K_{norm}\right) \\ K_{norm} \end{cases} \qquad (28)$$

$n\Delta t$

$K_n =$

K_norm, K_init, and t_init are found by examining the behavior of the alg and tuned for specific effects. However, the values K_init = 10, provide fast convergence because the error is expected to be high; and K_norm = 10 after t_init at 3 seconds provide good performance